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ORIGINAL PAPER

Future of *Abies pindrow* in Swat district, northern Pakistan

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Abstract : Swat district is a biodiversity hub of Pakistan. The plant species, especially trees, in the Swat District are exposed to extinction threat from global climate change. Maximum entropy (MaxEnt) modelling of species distribution, using HADCM3 A2a global climate change scenario, predicted a considerable change in the future distribution of *Abies pindrow* (Royle ex D.Don) Royle. AUC (area under the curve) values of 0.972 and 0.983 were significant for the present and future distribution models of the species, respectively. It is clear that bioclimatic variables such as the mean temperature of the warmest quarter (bio_10) and the annual temperature range (bio_7) contribute significantly to the model and thus affect the predicted distribution and density of the species. The future model predicts that by the year 2080 population density will have decreased significantly. The highest density of the species is recorded in the eastern and western borders of the Valley in the areas of Sulatanr and Mankial. The changes in density and distribution of the species can have considerable impact, not only on the tree species itself, but on the associated subflora as well.

Keywords: Vegetation mapping, *Abies pindrow*, climate change, predictive models, Swat Valley

Introduction

The Swat Valley, well known for its biodiversity, is in the North West Frontier Province of Pakistan at 34°34′ to 35°55′ N and 72°08′ to 72°50′ E (Shinwari et al. 2003) and bounded by Chitral and Ghizer on the north, Indus Kohistan and Shangla to the east, Bunir and FATA Malakand Agency on the south and district Dir on the west (Anon 1998). The plant species especially, trees in the Swat District are exposed to extinction threat from global climate change. Most of the naturally occurring plants of the valley are of high economic, medicinal and ecological value and have given Swat Valley a key role in the Medicinal and Aromatic Plants (MAPs) market of the region. (Shinwari et al. 2003).

MAPs have been used for thousands of years in human history (Samuelsson 2004) by different civilizations and for all sorts of ailments. These plants have specific growth requirements and if these requirements are not fulfilled the plants will vanish. Anthropogenic changes are the most factors observed recently on regional and global scales that affect natural vegetation (Song et al. 2004). Some species are sensitive to minute changes in the climate as Beigh et al. (2005) have pointed out for *Aconitum heterophyllum* (Wall) in the Himalayan region. The current study was carried out to model the impact of changing climate on the distribution of the forest trees of the Swat Valley especially *Abies pindrow* (Royle ex D.Don) Royle which provides a lifeline for the subflora especially MAPs of the area.

Predictive modelling is a useful tool for the conservation of species because it enables estimation of the extinction probabilities of species due to climate change. Modelling can provide powerful decisive tools for conservation planners. We used the latest modelling tools available to model the current and future distribution of *Abies pindrow*. Our objective was to understand the effect of climate change on the vegetation dynamics of the area as a basis for planning to counter or avoid any permanent damage to the precious flora of the area.

Abies pindrow was selected for the study as it is a native plant of the Valley that grows at an elevation range of 2,000–4,000 m. It typically grows in moisture rich and cold areas and reaches heights of 40–60 m and diameters of 2–2.5 m. In Swat Valley, it is very well known for its medicinal and economic values. This is one of the most expensive plants used for timber and construction material. The plant's tincture or decoction is used to treat coughs, phthisis, asthma, catarrh of bladder and other pulmonary infections. Its fresh juice is given to infants to treat fever and respiratory infections. The powder of leaves is mixed with powder of *Adhatoda vasica* L. leaves and honey to treat haemoptysis (Nad-

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karni 1927). The tree is also a common ornamental plant in the area (Baquar 1995) while the wood is used for construction of doors, windows, houses, and furniture, and the tree branches are used as fuel wood.

The predictive modeling is a common practice to investigate ecological, bio-geographical and conservation issues of species (Peterson 2007). There are a variety of species distribution models (Guisan and Thuiller 2005), some of which require species presence-absence data while others use "presence only data" and do not require "absence data" or they assume pseudo-absence (Soberón and Peterson 2005; Phillips et al. 2006; Chefaoui and Lobo 2008; Hirzel and Le Lay 2008; Jiménez-Valverde et al. 2008; Soberón and Nakamura 2009; Lobo et al. 2010). Predictive models are regarded as useful tools for the conservation of species because they enable estimation of the extinction probabilities of species due to climate change (Thomas et al. 2004). These integrative programs connect geospatial data with species-based information to identify priorities for conservation actions (Scott et al. 1996). MaxEnt modelling technique was applied to the study because it uses "presence only" data and is known to be a highly precise predictive modeling method (Elith et al. 2011).

Materials and methods

We sampled the presence of *A. pindrow* in randomly selected plots at 23 different localities of District Swat during 2007-08 and 2010-11. For accurate spatial location we used a RedHen DX-GPS system. A Garmin GPS was connected to a Nikon D300 camera to locate and photograph trees, and store data for later computer processing. Over 2000 photographs of different plant communities were captured and the metadata were extracted using the BR EXIF extractor, a freeware available online [http://www.br-software.com/extracter.html; visited 07/08/2011]. The software has the ability to transform metadata into CSV comma delimited text file format which can then be analyzed using MaxEnt software (Phillips et al. 2004). The MaxEnt method of predictive modelling was followed as prescribed by Phillips (2006) using the HADCM3 A2a climate change scenario (Collins et al. 2001) that predicts decreasing precipitation [-20 mm/year] and increasing temperature of around 4 degree Celsius to the year 2080. The bioclimatic layers (Table 1) in GIS compatible format were downloaded from the Worldclim website (WorldClim 2011).

Some of the software we used was optional, e.g. the Br EXIF extractor was only needed for the extraction of metadata from images taken with DX-GIS hardware. Krename was only used to quickly rename a large sum of files, which could also have been done in MS DOS. We also used ArcGIS version10 (ArcMap) licensed by ESRI 2011 in map development.

Results were assessed using AUC (area under the curve) values generated by the Maxent software. The general agreement on the AUC value is that the model is "good" if the value is over 0.8, while the value of over 0.9 is considered highly accurate (Luoto et al. 2005).

Table 1. Bioclimatic variables and their description (source: WorldClim, 2011).

No.	Bioclimatic variable	Description
1	bio_1	Annual mean temperature
2	bio_2	Mean diurnal range (mean of monthly (max temp-min temp)
3	bio_3	Isothermality (100*mean diurnal range/annual temperature range) or (bio_2/bio_7*100)
4	bio_4	Temperature seasonality (standard deviation *100)
5	bio_5	Max temperature of warmest month
6	bio_6	Min temperature of coldest month
7	bio_7	Temperature annual range (bio_5 - bio_6)
8	bio_8	Mean temperature of wettest quarter
9	bio_9	Mean temperature of driest quarter
10	bio_10	Mean temperature of warmest quarter
11	bio_11	Mean temperature of coldest quarter
12	bio_12	Annual precipitation
13	bio_13	Precipitation of wettest month
14	bio_14	Precipitation of driest month
15	bio_15	Precipitation seasonality (coefficient of variation)
16	bio_16	Precipitation of wettest quarter
17	bio_17	Precipitation of driest quarter
18	bio_18	Precipitation of warmest quarter
19	bio_19	Precipitation of coldest quarter

Results and discussion

MaxEnt predicted the current species distribution to extend into the neighbouring districts towards the east and the west with a decrease in population density, while the highest species density was predicted for the eastern and western borders of the Valley in the areas of Sulatanr and Mankial (Fig. 1 A and B). In order to evaluate the validity of the present prediction of the model, a ground-truth survey was carried out, which confirmed the results of the model.

The Jackknife analysis for the present distribution probability (Fig. 2 A, B) of the Area Under Curve (AUC) showed that the highest contribution was attained by bio_10 and bio_7 climatic variables, which are (mean temperature of the warmest quarter) and (temperature annual range [bio_5-bio_6]), respectively. Variables contributing the least to distribution were bio_13 (precipitation of wettest month) and bio_16 (precipitation of wettest quarter). Accuracy was measured by the area under the receiver operating characteristic (ROC) curve. An area of 1 represented a perfect test, while an area of 0.5 represented a worthless test.

For future projection, the model showed a different trend: bio_6 was the main contributing variable along with bio_1 and bio_11, while bio_14 was the least contributing variable (Table 2 and Fig. 2 A, B). Bio_14 was precipitation of the driest month, and was not a significant factor in the distribution of *A. pindrow* (Fig. 2 A, B). Predictive models

The AUC values obtained for the species for present distribution models yielded highly significant results (Table 2). The population density of *A. pindrow* was predicted to be negatively affected by climate change. The Swat Valley would support fewer *A. pindrow* in 2080 and the southern parts of the Valley would not support the species after 2080.

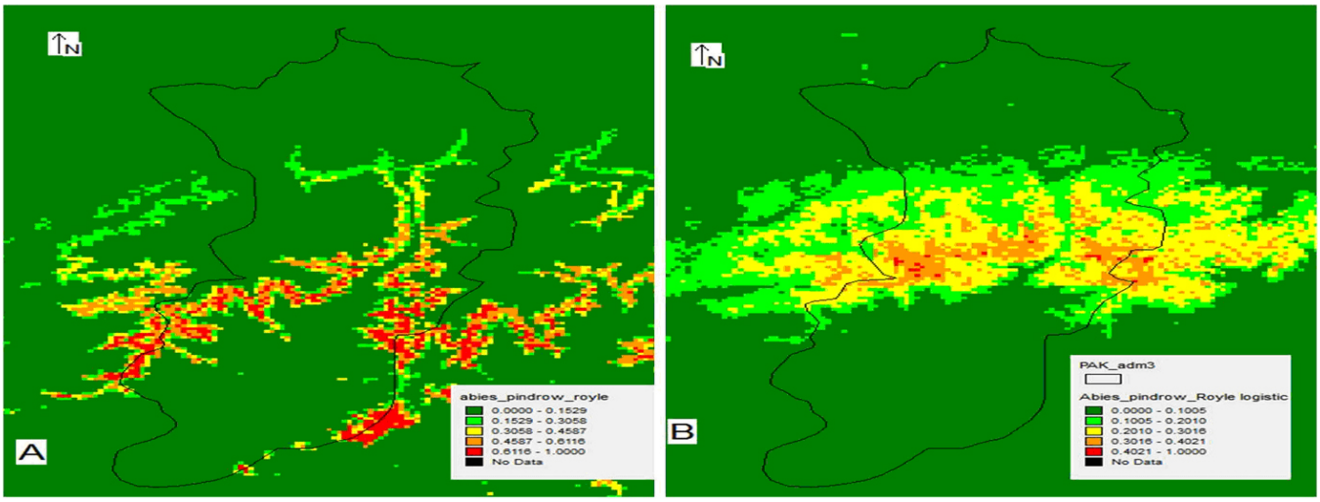

Fig. 1. A. Present distribution of *Abies pindrow*; B. Future projected distribution of *A. pindrow*.

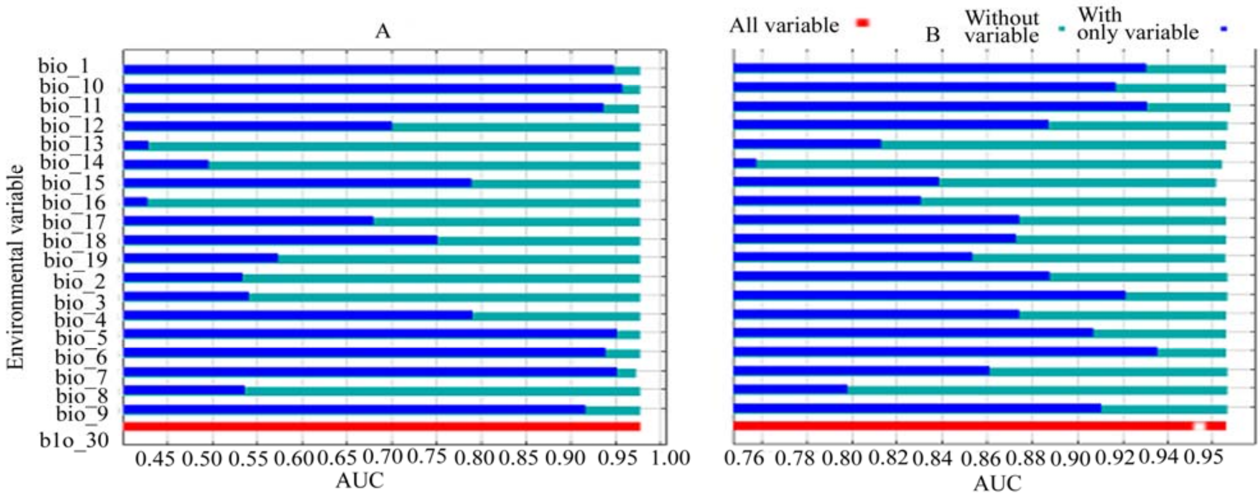

Fig. 2. A. Jackknife of AUC (area under the curve) for *Abies pindrow*, present prediction model; B. Jackknife of AUC for *Abies pindrow*, future prediction model; results of a Jackknife AUC of variable importance for *Abies pindrow* in the A2a scenario using all point localities and 19 bioclimatic variables. (Phillips et al. 2006).

Table 2. Training AUC values, important variables and percentage contribution of *Abies pindrow* for the present and future predictive models

Species	Present distribution model			Future distribution model		
	Training AUC	Important variables	Contribution (%)	Training AUC	Important variables	Contribution (%)
Abies pindrow	0.972	bio_11	74.8	0.983	bio_15	27.4
		bio_7	14.7		bio_6	15
		bio_15	10.1		bio_12	14.4

Colonization of new habitats

Species never live on their own (Hizrel and Le Lay 2008) and always interact with their environment, both physical and biological. Some species are sensitive to minute changes in the climate as Beigh et al. (2005) pointed out for *Aconitum heterophyllum* in the Himalayan region. We conclude that the *A. pindrow* will not suffer regional extinction, but its current habitat and population density will be significantly affected. As a result, the sub-flora dependant on *A. pindrow* will either move with their overstory trees or suffer extinction.

A general trend of elevational shifts of species has been observed in the Hindu Kush-Himalayan region as a consequence of global warming or climate change. Song et al. (2004) reported the effect of climate change on the northwards movements of tree species, including *Abies* spp. and *Picea* spp. We predict a similar climate change response for *A. pindrow*. As the northern

part of the study area is at high elevation colder than the southern part, the distribution of *Abies pindrow* is predicted to shift northward in future (Fig. 1 B).

Similarly, variation in other bioclimatic variables, such as bio_15, “precipitation seasonality” or (coefficient of variation), means that habitats now occupied by *A. pindrow* would not, assuming forecast changes in global climate, receive rainfall in future years according to historic patterns of seasonality. This would be especially true in the Hindu Kush Himalaya, as explained by Ahmad et al. (2010).

Our results suggest that global climate change will have a significant effect on the distribution of some of the important tree flora of the Swat Valley and will eventually cause scarcity of the Non Timber Forest Products (NTFPs), especially MAPs, which typically occupy shady or semi-shady niches beneath the forest canopy (Adnan and Hölscher 2011). We anticipate that the change in climate will force trees like *Abies pindrow* to either shift their distribution or suffer local extinction. Either situation would create serious socio-cultural problems related to the health and economy of the communities residing in Swat Valley.

Lack of public awareness of this anthropogenic change is widespread. Neither the Federal Government of Pakistan nor the Provincial Government of Khyber Pukhtun Khwa (KPK) has developed strategy to deal with the consequences.

There is a clear need for alternative crops to support the already exploding population of the Valley: availability of arable land and water resources are in decline. Selection of suitable alternative species will be critical because some species will not be able to survive the future climatic conditions. Serious changes to conservation policy will be needed at a governmental level, and strict measures will be needed to implement conservation policy.

The area of predictive modelling of species is relatively new and therefore, there are many things which need to be considered before using the results of such models for decision making. Many authors have reservations regarding the results and parameters used. For example, AUC values and the use of terminology in the interpretation of results of models are both questioned. The input data, such as presence-only data, and pseudo-absence of species, and selective use and derivation of bioclimatic layers, and others are the focus of critical debate in the current scientific arena (Pulliam 2000; Soberón and Peterson, 2005; Chefaoui and Lobo 2008; Elith et al. 2011).

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